

A PERIGLACIAL ANALOG FOR LANDFORMS IN GALE CRATER, MARS.

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Summary: Several features in a high thermal inertia (TI) unit at Gale crater can be interpreted within a periglacial framework. These features include polygonally fractured terrain (*cf.* ice-wedge polygons), circumferential patterns of polygonal fractures (*cf.* relict pingos with ice-wedge polygons on their surfaces), irregularly-shaped and clustered depressions (*cf.* remnants of collapsed pingos and ephemeral lakes), and a general hummocky topography (*cf.* thermokarst). This interpretation would imply a major history of water and ice in Gale crater, involving permafrost, freeze-thaw cycles, and perhaps ponded surface water.

Background: Gale crater is a ~150 km diameter, impact structure located at 5°22'S, 137°051'E. It sits on the dichotomy that separates the southern highlands from the northern lowlands. Gale includes a 5.5 km high, central mound of sediments that is surrounded by a moat-like topographic low. MSL landed on the low, close to a region of early interest because of its location distal to an alluvial fan and its high TI (Fig. 1). The MSL rover will analyze this unit at Yellowknife Bay (Fig. 2). Geomorphology of the high TI unit is presented here, based on HiRISE data.

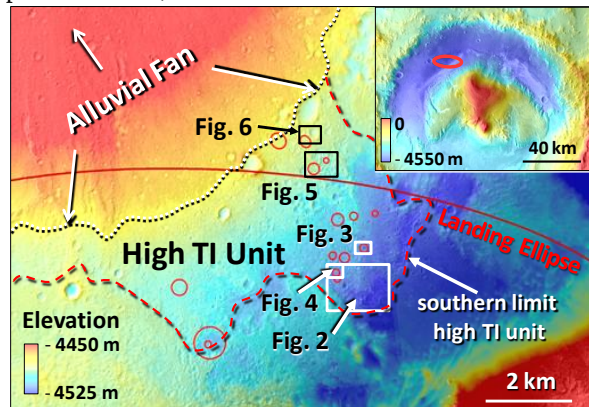


Fig. 1. N. part of Gale landing ellipse (stretched elevation on HiRISE) showing locations of high TI unit, Figures 2-6 (rectangles) & circumferential polygons (red circles & ovals). Inset (upper right) shows location of landing ellipse (red oval) in Gale (elevation on THEMIS Daytime IR data).

Geomorphology: The high TI unit is a relatively bright feature (Fig. 2). It occupies some of the lowest elevations in the crater (< -4475 m) and is highly fractured. In places, it appears to underlie adjacent units, suggesting that it is older than those units. The high TI unit has hummocky topography, and it has a lower density of craters than the darker sediments to the south and southeast (Fig. 2). The lowest part of the unit, (< -4527 m, within the red contour of Fig. 2) is less hummocky and has fewer craters, fractures, and depressions than other parts of the unit.

Many of the fractures form polygons, 4-30 m across. The polygons commonly are organized into circumferential patterns, 100-600 m diameter (Figs. 3-4). 14 of these have been mapped in the area of Fig. 1. There are also many irregularly shaped depressions, 50-700 m diameter. These have sloped and rounded borders and tend to occur in clusters (Figs. 5-6). While originally assumed to be impact craters, the morphology and clustering of these depressions present the possibility of a non-impact origin (see Discussion).

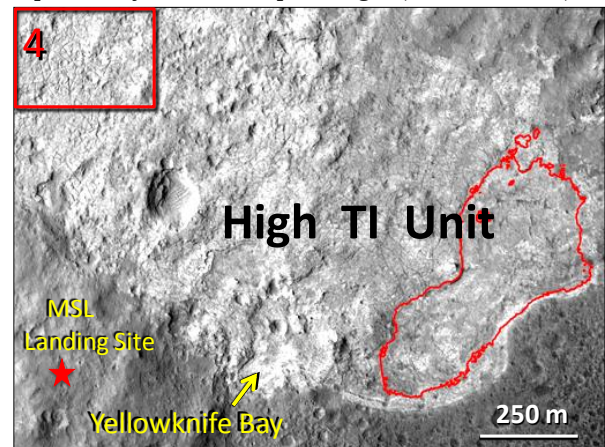


Fig. 2. High TI unit. Red contour (- 4527 m) encloses lowest part of unit. Location of Fig. 4 (red rectangle).

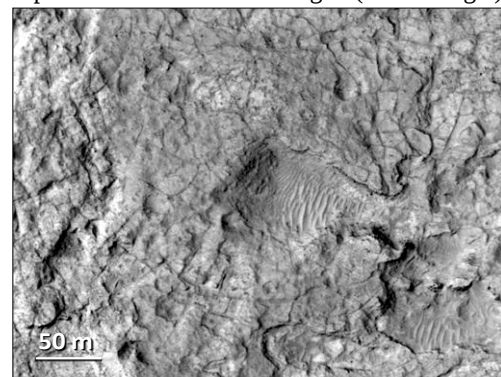


Fig. 3. Circumferential polygons in high TI unit.

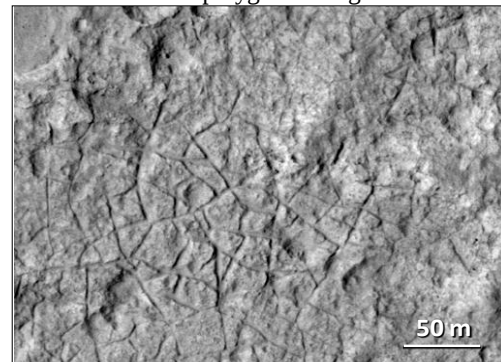


Fig. 4. Circumferential polygons in high TI unit.

Discussion: Periglacial features in the Arctic provide an analog for the suite of features described in the high TI unit. For example, Arctic ice wedges form flat and nearly flat circumferential patterns of polygons where ice in the core of pingos has melted (Fig. 7). These are similar to the circumferential patterns in the high TI unit (Figs. 3-4). In addition, many Arctic ice wedge polygons are associated with variously shaped and clustered lakes. Such lakes occur where there has been pingo collapse (Fig. 6 inset) and where there are

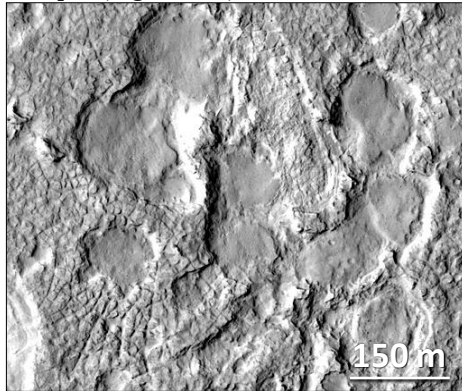


Fig. 5. Irregular, clustered depressions in high TI unit.

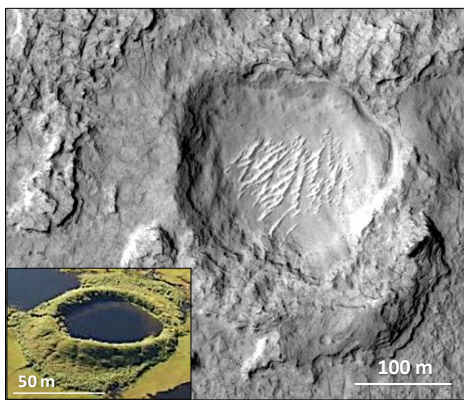


Fig. 6. Irregular depression in the high TI unit. Inset (lower left), collapsed pingo in the Arctic.

hollows in the thermokarst topography common to areas of permafrost. Those lakes resemble the irregular depressions in the high TI unit (Figs. 5-6) in size, form, and clustering. Lastly, the hummocky terrain of periglacial landscapes is reminiscent of the hummocky surface of most of the high TI unit (Fig. 2).

Age estimates for Gale range from 3.8 Ga (for the impact event) to 3.6 Ga for sediments within the moat [1]. This places early sedimentation in Gale in the Late Noachian/ Early Hesperian – a period generally thought to be wet, with rivers draining from the southern highlands towards the dichotomy and northern lowlands. In addition, hydrologic models suggest that “Gale is uniquely situated to receive substantial influx of groundwater” [2]. Further, the large diameter of Gale suggests that it could have had long-term, impact-related hydrothermal flow adding warm water from depth to the surface and near surface of the crater [3-5].

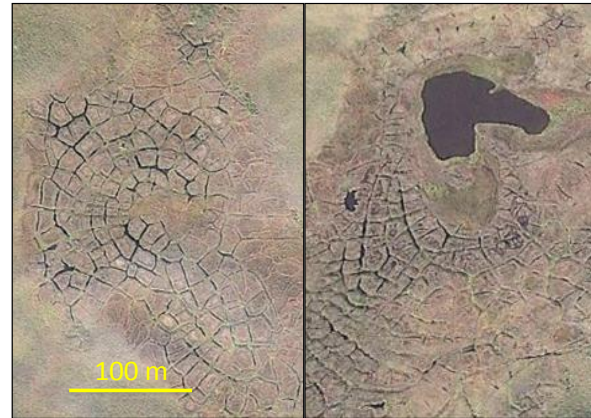


Fig. 7. Circumferential patterns of polygons surrounding melted pingos in the Arctic.

Taken together, the age, geologic setting, hydrologic modeling, and potential for hydrothermal flow suggest that Gale could have contained significant subsurface water and possibly even ponded surface water, early in its history. As the climate cooled, lakes and subsurface water are likely to have frozen, and a period of periglacial freezing-thawing or freezing-sublimation would have ensued, resulting in ice-related alterations to the land surface. Preservation of these periglacial landforms in Gale crater may have involved subsequent cover by sediments/dust and/or cementation due to evaporative processes resulting from freezing or later desiccation. The paucity of craters in the lowest part of the high TI unit (Fig. 1) might support the above scenario, as an uncratered surface could be attributable to the presence of a water body or an ice-covered lake during the period when surrounding units were being cratered. However, other explanations for a rarity of craters can include rapid burial / recent exposure or a surface character that does not retain craters.

Analysis of the high TI unit will continue and will incorporate methods suggested by [6] for assessing meso-scale, raised-rim-depressions on Mars.

Conclusions: A periglacial analog fits a suite of features in the high TI unit of Gale crater, including the polygons, their circumferential patterns, the irregularly-shaped and clustered depressions, and the hummocky topography. This interpretation implies a substantial history of water and ice in Gale crater. While this scenario is consistent with geologic context and views of martian climate evolution, identification of actual periglacial features in the high TI unit would provide concrete evidence for such a history, thus allowing more definitive inferences regarding past habitability.

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References: [1] Thomson B. et al. (2011) *Icarus* 214, 413-432. [2] Andrews-Hanna J. et al. (2012) 43rd LPSC, Abstract #2706. [3] Newsom H. et al. (2001) *Astrobiology* 1, 71-88. [4] Abramov O., Kring D. (2005) *JGR* 110, E12S09, doi:10.1029/2005JE002453. [5] Ivanov B., Pierazzo E. (2011) *Met. Planet. Sci.* 46, 60-619. [6] Burr D. et al. (2009) *PSS* 57, 579-596.